Technology Roadmap: Intelligent Mobility Technologies

CENTER FOR AUTOMOTIVE RESEARCH

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Acknowledgments

This whitepaper provides a summary of work produced by the Center for Automotive Research (CAR) for Michigan Economic Development Corporation (MEDC). The authors of this white paper would like to thank our colleagues at CAR – Carla Bailo, Kristin Dziczek, and Eric Paul Dennis – for their input and guidance throughout this project. Additional assistance was provided by Terni Fiorelli who coordinated the research effort and Shaun Whitehouse, who created the infographics.

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For citations and reference to this publication, please use the following:

Bahrani Fard, Z., Brugeman, V. S. (2019). Technology Roadmap: Intelligent Mobility Technologies. Center for Automotive Research, Ann Arbor, MI.

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CAR's mission is to conduct independent research and analysis to educate, inform and advise stakeholders, policymakers, and the general public on critical issues facing the automotive industry, and the industry's impact on the U.S. economy and society.

Introduction

The automotive, transportation, and mobility industries have experienced transformative changes due to advancements in connectivity and automation technologies, data analysis, and the rise of new mobility services. With such rapid changes in the industry's landscape, an understanding of where technological development is at present and where it is likely headed is helpful to guide future decision-making.

With funding from the Michigan Economic Development Corporation (MEDC), the Center for Automotive Research (CAR) has prepared this technology roadmap based on internal research and a thorough analysis of available industry reports. CAR researchers vetted the study conclusions with critical input from a group of subject matter experts. This white paper updates CAR's previous Technology Roadmap (Smith, Spulber, Modi, & Fiorelli, 2017) published in 2017.

The World We Know

It is an exciting time in the automotive and transportation industries. Innovations in data analysis methods, especially in artificial intelligence (AI) and machine learning (ML), have led to unprecedented improvements in vehicle automation systems. These advancements have led to breakthroughs such as Waymo being the first company to put a Level 4[1] vehicle on public roads in 2017.

Similarly, automakers, tier 1 suppliers, and technology companies have put significant effort toward development, updates, and improvement of advanced driver assistance systems (ADAS). ADAS systems developed over the past ten years focus on improving driver safety and efficiency via a range of driver assistance and warnings. As with many new technologies, the majority of ADAS systems were first available on luxury vehicle models, but increasingly ADAS systems are becoming available on mainstream models as well. The systems that are focused on safety are deployed even more frequently, in part due to mandates, such as the 2018 the National Highway Traffic Safety Administration (NHTSA) mandate that all new vehicle models must be equipped with rearview video systems. (Sui, 2018)

From a connectivity perspective, the expansion of wireless networks and improvements in communication technologies have resulted in new ways for vehicles to connect with other vehicles, the infrastructure, and beyond. With vehicle-to-everything (V2X) technologies, vehicles are no longer isolated from their surroundings. Vehicle-to-vehicle (V2V) technologies enable vehicles not only to communicate with other vehicles on the road but also to transfer and receive information from roadside units through vehicle-to-infrastructure (V2I) systems.

Vehicle connectivity has been a topic of great debate in auto technology and regulatory forums with many open discussions around cellular-V2X, security, and data privacy. While many were expecting to see a mandate on V2X technologies, in 2018, the U.S. Department of Transportation (USDOT) clarified that the agency will remain technology-neutral and will not push for either dedicated short-range communication (DSRC) technology or cellular 5G technology (U.S. Department of Transportation, 2018).

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[1] According to SAE International's J3016 Levels of Automation. On a 0-5 scale, where 5 is fully automated.

In the absence of a technology mandate, the many V2X technology deployments nationwide are using different technologies.

Over the past few years, a new transportation sub-industry has emerged: the mobility industry. What distinguishes the mobility industry from transportation is the focus on increasing accessibility through leveraging information technologies and the sharing economy. These new areas of focus have led to the rise of innovative mobility services in high-density urban areas. Some of these services, such as carsharing, have been available for decades. Since the 2010s, however, the mobility industry has expanded with new business models and services including ridesourcing (such as Uber and Lyft), ridesharing, microtransit, mobility-as-a-service (MaaS), and bikesharing. Scootersharing is the most recent mobility service that quickly became a part of the mobility landscape in 2018. Although scooter popularity has risen because of low barriers to entry and easy access, some cities such as San Francisco, California (ABC News, 2018), Beverly Hills, California (Tchekmedyian, 2018), and Atlanta, Georgia (City of Atlanta, 2019) temporarily banned scooters due to their interference with pedestrian traffic, and other issues.

Technology Drivers & Business Change

Technology advancements are pushing the bounds of vehicle automation, connectivity, and innovative mobility services. However, companies are finding the need to partner and work with each other at a pace previously unseen to develop these technologies. Many of these partnerships arise due to the costs and risks associated with developing vehicle automation, the transportation pieces of smart cities, and the uncertainty surrounding whether innovative mobility services will be successful and robust enough to entice people away from personal vehicle ownership. CAR is tracking how companies are working together and on which business models in a separate project dubbed the “CAR Mobility Web.” Some of the Mobility Web information is relevant to include in this Roadmap because the connections between companies are a vital force that is driving mobility business models forward.

Figure 1 depicts how automakers are working with each other and with supply chain companies to develop future mobility technologies and services. Of particular note is how automakers are choosing to invest through strategic acquisitions. For example, Ford acquired the micromobility company Jump, GM acquired autonomous vehicle technology company Cruise Automation, and then Honda also committed to investing USD 2.75 billion in Cruise (Hanley, 2018). German-based companies Daimler and BMW have merged their mobility efforts completely. These partnerships are becoming the backbone of the future of mobility.

Figure 1. Noteworthy Automaker Partnerships for Mobility and Vehicle Automation

	Automaker	Non-Traditional Supplier	Tier 1 Supplier
BMW	FCA	Amazon, Intel, Mobileye, Moovit, HERE, Innoviz, Blackmore	Delphi
Daimler	BMW, Geely, Smart	EM Motors, Nvidia, Sila Nanotech, Quanergy	Bosch
FCA	BMW	Intel, Mobileye	Delphi
Ford	VW, Audi, Rivian	Autonomic, Argo AI, Qualcomm, Amazon, Clinc, Velodyne, Transloc, Civil Maps, Team Edison	
GM	Honda	Aeye, Strobe	Michelin
VW / Audi	Ford, JAC, SEAT	Aurora, Mobileye, Apple, Microsoft, WirelessCar, Argo AI, AI Driving, Amazon, Huawei, Luminar, Samsung, Qualcomm	

Partnership | Acquisition | Subsidiary | Investment | Joint Venture

	Mobility Company	Other
BMW	Summon, Scoop, ReachNow, FreeNow, ShareNow, DriveNow, May Mobility, Alaka'i Tech, Access by BMW	Walmart
Daimler	Via, Uber, MyTaxi, Moovel, Getaround, Flinc, Croove, Turo, Car2go, ReachNow, FreeNow, ShareNow, Careem, Torc Robotics	Udacity
FCA	Waymo	Walmart
Ford	Lyft, Spin, RideOS, Postmates, Motivate, GoBike, Ford Smart Mobility, Bridj, GoRide Health, Agility Robotics, Ford Autonomous Vehicles	Walmart, Domino's
GM	Uber, Maven / Maven Gig, Lyft, Sidecar, Cruise, ARIV, DoorDash	OnStar, Bechtel
VW / Audi	Zipcar, WeShare, Moia, Gett, Champion Motors, Inclusive Mobility, On Demand	Walmart, Italdesign

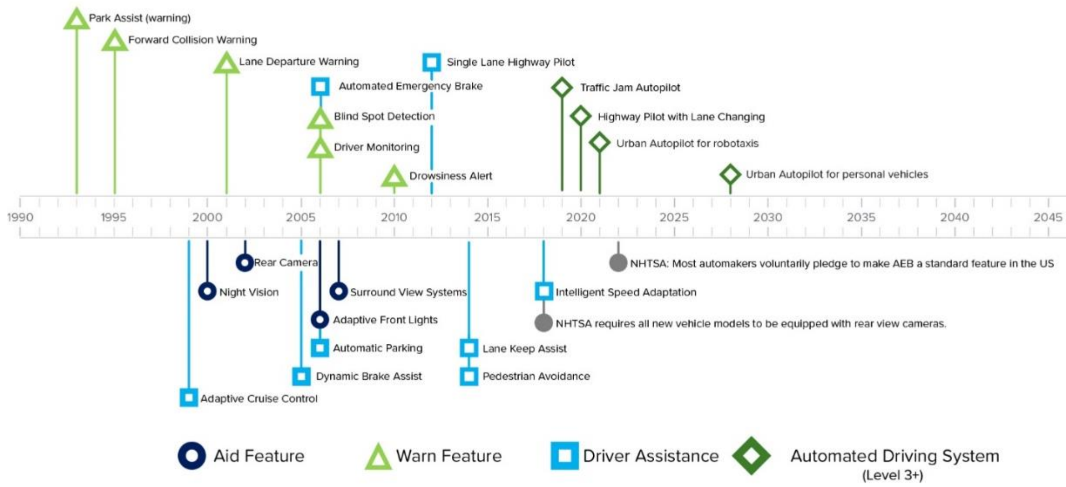
Source: CAR Research

The World on the Horizon

The direction and speed of advancements in intelligent mobility technologies depend on multiple factors that will be discussed later in this document. To capture the most important future directions of the industry, the CAR team has complied the finding of multiple academic, industry and also its in-house knowledge together and has the projection validated by subject matter experts from the industry.

Significant investments in ADAS and vehicle automation system development from emerging technology companies and non-traditional suppliers have disrupted the automotive industry. To ensure appropriate responses to these disruptions, established automakers and suppliers have started their own automated vehicle R&D units to compete in the future mobility market.

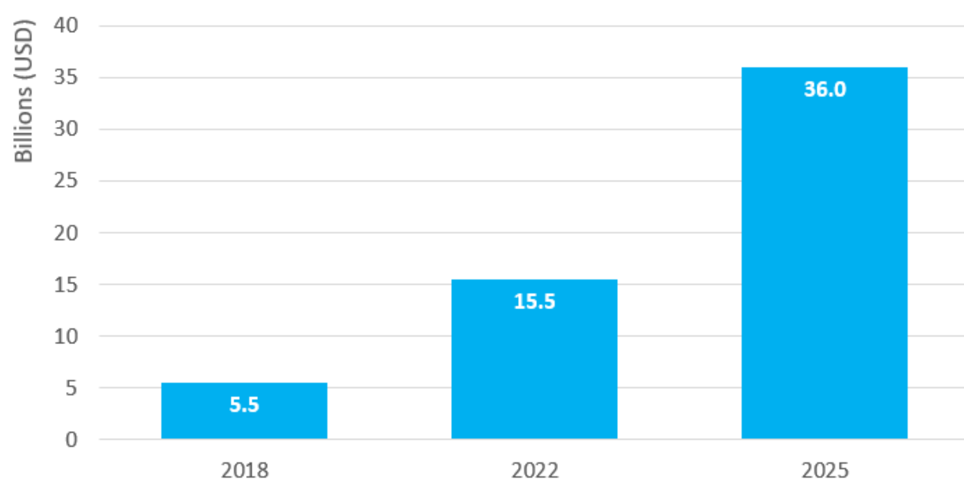
Figure 2. Timeline for Launches of ADAS and Automated Driving Features, 1990 to beyond 2022



Source: CAR Research

The ADAS market is expected to grow considerably over the next few years due to the proliferation of existing ADAS systems and the anticipated arrival of automated driving systems. Regulatory mandates and consumer adoption also are among the factors affecting the ADAS market. Forecasts suggest the dollar value of the ADAS market to grow three times larger by 2022, as Figure 3 depicts.

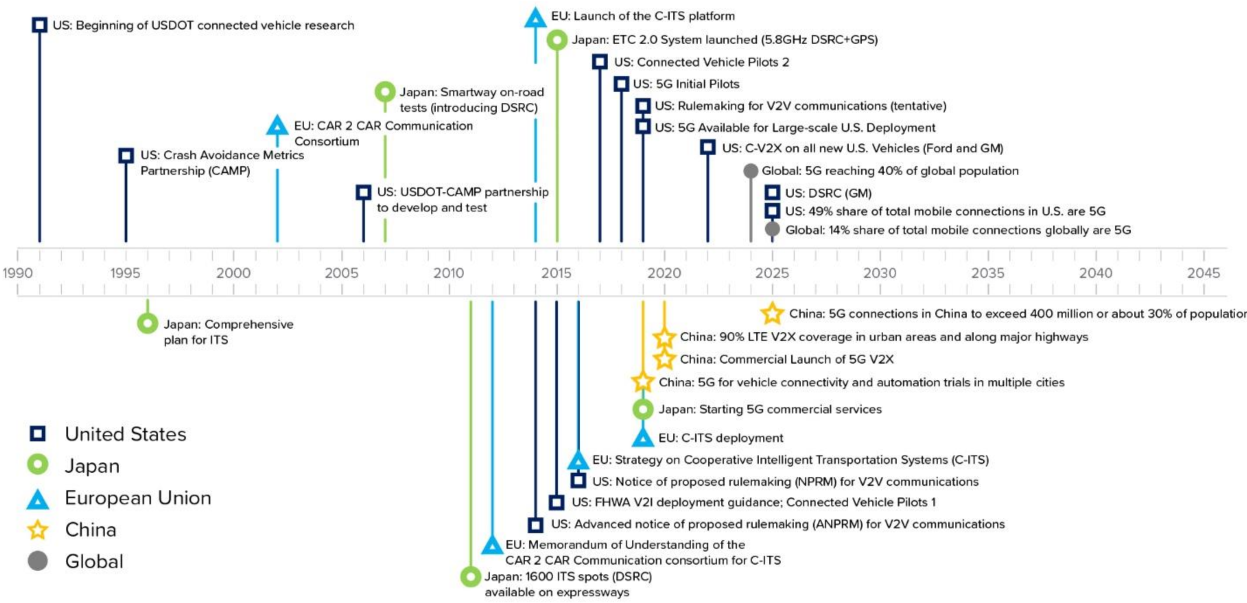
Figure 3. ADAS Market Size Forecast, 2018 to 2025



Source: CAR Research

The connected vehicle market continues to evolve along two competing tracks: the well-known DSRC and the promise of cellular CV2X which hinges on 5G technology deployment. Many companies have opted to pursue 5G because the technology is expected to have the low latency of a DSRC network with the ubiquity of cellular. Ford, for example, announced that by 2022, it will equip all new vehicles with CV2X capabilities (Abuelsamid, 2019). Toyota, which had initially focused it's connectivity efforts on DSRC, announced in April of 2019 that they plan to discontinue those efforts (Shepardson, 2019). In the absence of a mandate, it appears companies are hedging their bets on the promises of 5G. As Figure 4 below shows at present, the future of connectivity seems to be headed in the CV2X direction.

Figure 4. Timeline for Vehicle Connectivity, 1990 to beyond 2040

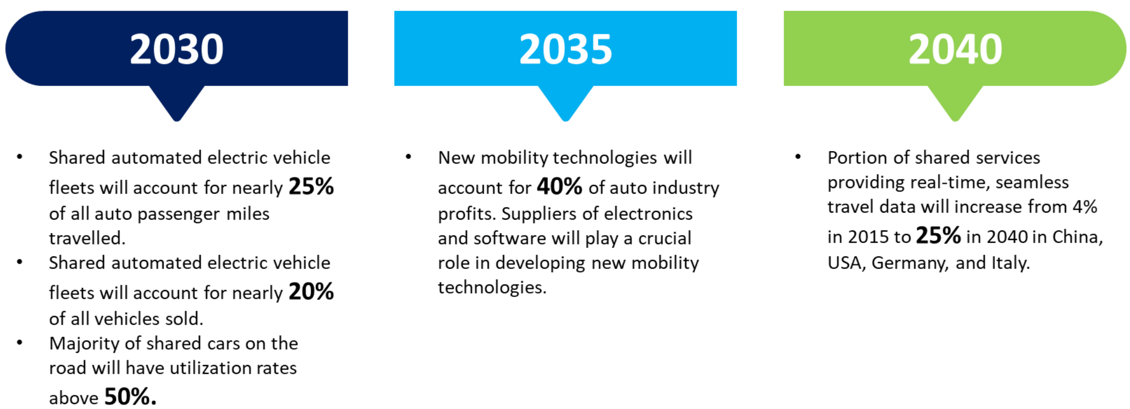


Source: CAR Research

As expected, innovative mobility services have diversified and expanded dramatically over the past few years, especially since 2017. Affordability, accessibility, efficiency, and convenience are among the reasons why many urban dwellers, especially younger people and residents of big cities, have chosen to use these services for their short, long, and even first-mile, last-mile trips.

Figure 5 shows the global forecast for innovative mobility services and automation technologies from 2030-2040, based on CAR research and SMEs validation. Of note is the projection that by 2035, new and innovative mobility technologies will account for 40 percent of automotive industry profits.

Figure 5. Global Timeline for Innovative Mobility Services and Automation, 2030 to 2040

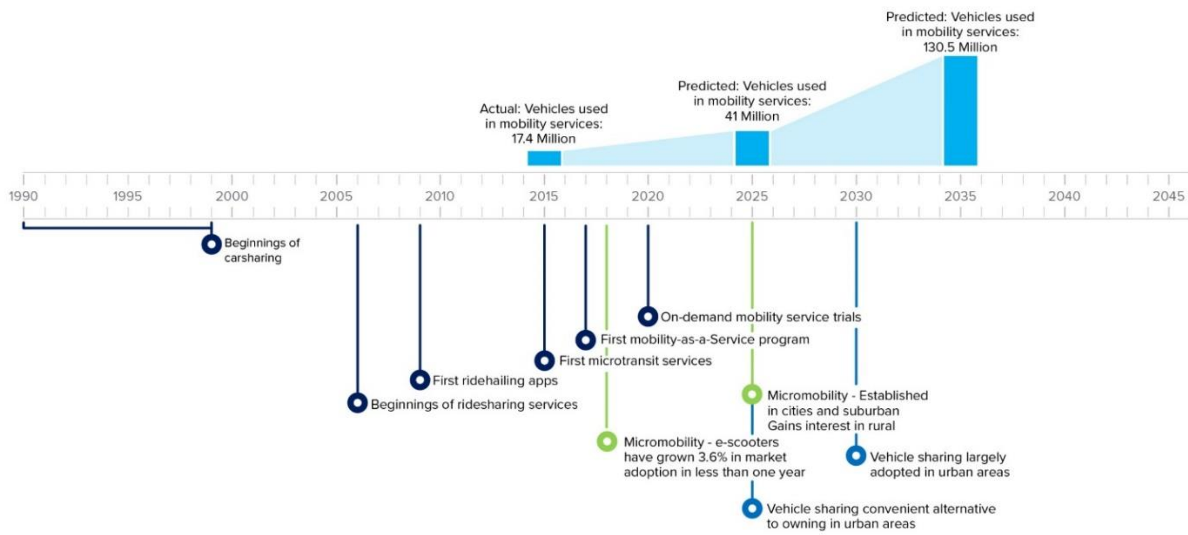


Source: CAR Research and SMEs Validation

In 2017-2018, a few automated shuttle technology companies began testing and operating small vehicles (4-6 people capacity) in select urban areas. Later in 2018, a few of those companies, such as May Mobility, were able expand their service to more cities.

The convergence of current and future innovations in connectivity, automation, electrification, and data analysis is expected to support the growth of shared, electric, and automated vehicles sometime in the 2030s, as Figure 6 depicts.

Figure 6. Global Timeline for New Mobility Services and Automation, 1990 to 2040



Source: CAR Research

Enablers and Threats

Technological availability and adoption can be affected by multiple factors, such as the availability of enabling technologies and the costs, consumer acceptance, and infrastructure required to support them. Over the past few years, many automakers and connected and automated vehicle (CAV) technology developers have made promises to introduce highly and fully automated vehicles to the market shortly. However, many have not met those goals due to the combination of cost, consumer, and infrastructure factors.

Legislation, Regulation, and Market Demand

Legislation, regulation, and market demand can create a more certain framework within which industry forecasts and expectations are more reliable. Absent regulatory or market-driven certainty, technology investments, innovations, and deployments can be stopped, delayed, or executed unevenly across different jurisdictions. The availability of supportive legislation and regulations, however, can encourage a greater level of investments in the industry due by reducing investment risk.

Social Acceptance

The sharing economy, improvements in communication technologies, and the ubiquitousness ownership of smartphones have contributed to the growth of new mobility services, especially in dense urban areas and among younger people. The industry has also succeeded in increasing the availability, reliability, accessibility, and diversity of innovative mobility services which have added to their popularity.

The same cannot be said for connected and automated vehicles, however. Recent fatal crashes, missed deployment goals from industry leaders, unsolved regulatory and liability issues, and potential data privacy and security issues currently impact CAV technology development.

Infrastructure

The safe and successful implementation of intelligent mobility services is dependent on infrastructure readiness. The role of infrastructure will be far more critical for future automated vehicles deployments. In the absence of a human driver's intelligence, CAVs will have to rely on the information received from the vehicle's sensors and other inputs as well as from other road users and the infrastructure. Currently, state and local transportation agencies are working with industry partners to install in-road sensors and roadside units using various communication technologies.

Advancement in Key Technologies

Progress made in machine learning, deep learning, and neural network analysis has been crucial to the development of current CAV technologies. In addition to AI technologies, advanced sensor technologies (especially in cameras and LiDAR), object recognition, quantum and cloud computing, and 3D mapping and localization systems are needed to develop fully connected and automated technologies.

Cost versus Benefits

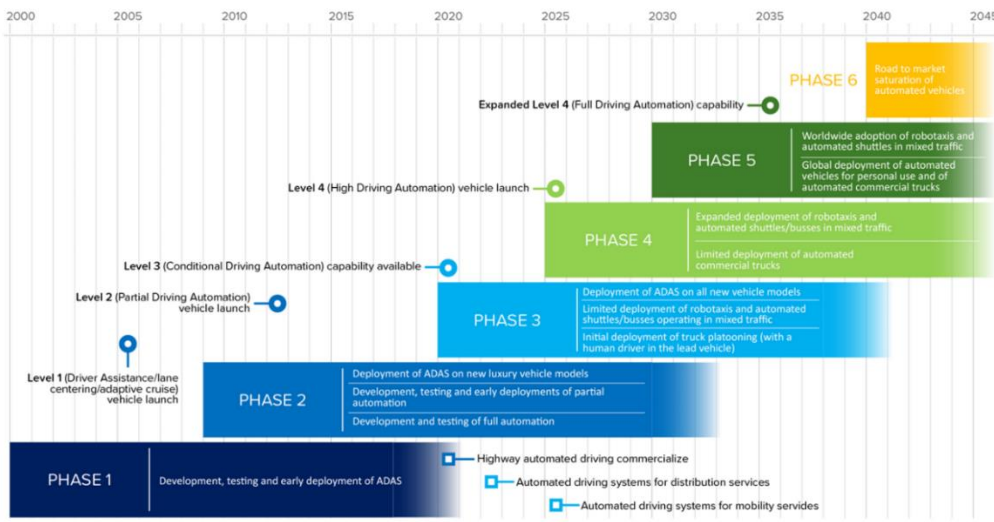
High technological costs is a substantial challenge toward adoption of CAVs. The cost of some CAV technologies, such as LiDAR systems, is currently so high that some companies, most notably Tesla, have opted not to use it for their CAV systems. However, many believe future technology innovations and reduced production costs of CAV components and systems will eventually drive down CAV costs.

Despite their high costs, CAVs have the potential for a multitude of safety, environmental, and convenience benefits. Achieving such improvements, however, relies upon regulations and processes that encourage *shared* use of CAVs. While shared AVs could result in alleviating congestion by reducing the number of vehicles on the road, on the other hand, operation of CAVs as privately-owned vehicles can offset the safety benefits and worsen traffic congestion, due to exteremly increased vehicle miles traveled (VMT). (Green Blatt & Shaheen, 2015)

Monitoring the Future

Industry stakeholders must carefully track trends and forecast upcoming changes in the rapidly evolving mobility landscape. Technological, social, regulatory, and industry dynamics are vital areas to watch closely in the coming years. New data analysis methods (specifically AI) and sensor technologies, emerging business partnership models, AV regulations and data privacy laws, as well as social acceptance are a few examples of potentially transformative industry trends. Success or failure in one or more of these areas has the potential to transform the intelligent mobility industry dramatically.

Figure 7. Advanced Driver-Assistance Systems (ADAS) and Vehicle Automation Technologies, 2000 to beyond 2040



Source: CAR Research

Conclusion

This report forecasts intelligent mobility industry trends based on the CAR team's research findings as well as input from subject matter experts. Our findings show that several factors can affect the industry's progress in the coming decades, including:

- Technology readiness: Safe and efficient operation of emerging mobility technologies relies on the availability and functionality of enabling technologies. In the case of CAVs, much remains to explore in key functioning areas such as human-machine interactions.
- Infrastructure: The existing infrastructure must be updated and enhanced to be able to respond to the expansion of intelligent mobility technologies. Many cities and state transportation agencies have started upgrading their infrastructure and zoning policies to accommodate the future development of these technologies. However, unclear regulations, technology failures, or state and local budget constraints may discourage further public investments in intelligent transportation systems.
- Industry collaborations: Cross-sector communication and stakeholder collaboration are needed to reduce technology production costs. Emerging partnerships among automakers and suppliers are expected to contribute significantly to CAV and innovative mobility service technology development in the next few decades. Also, industry collaborations with lawmakers can facilitate the process of CAV supporting regulations.

- Regulations and policies: Lagging regulations and unclear standards can curb technological progress as investors always seek to secure their investments by predicting industry trends.
- Social acceptance: The value of the technology relative to its cost coupled with safety and security concerns determine consumers' willingness to pay for new mobility technologies. Public education can be beneficial in improving the popularity of intelligent transportation technologies.

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